

Validation of the NOvA Far Detector CDR Geometry Simulation

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May 1, 2006 - Version 1

The recent changes to the Far Detector geometry reflected in the Conceptual Design Report have been incorporated into a new FFR geometry card file. This document describes the changes, and the validation of the cards in simulations.

Introduction

Two changes to the original TAVC (Totally Active Version C) geometry are incorporated into the CDR design, for mechanical reasons. They are

- Each block begins and ends with a vertically oriented plane (X-view),
- The extrusion external wall and internal webbing thicknesses are greater for vertically oriented planes (X-view).

These are incorporated into a new FFR file in the nova cvs repository, \$NOVA_FFR/detgeom/cdrc_far.ffr. This geometry is specified by default in the the sim_*.csh scripts in \$NOVA_SIM/scripts, and can be overridden with the -det flag.

Description

The geometry is implemented as described in table 3.2 of the CDR. The detector consists of 54 blocks of 31 planes, each beginning and ending with a plane of vertically oriented cells. The upstream cosmic shield has been approximated by an 18m x 18m x 3m thick plane of concrete, 5m upstream of the first active detector plane. Each block of planes is separated by a 1cm expansion gap, but without the corresponding PVC spacers.

Validation

The resulting geometry was validated with truth information from a series of small simulations.

Large Scale Geometry:

The global geometry of the detector was validated with 2 runs of ν_μ CC events, of 1000 (with concrete shield) and 10000 events (no shield). Fig. 1 shows the truth vertex Z distribution of the run with the shield, and fig. 2 shows it without. Fig. 3 shows the truth vertex X-Y distribution for the no-shield run.

Fig. 1: Truth Vertex Z distribution for the cdrc_far geometry, with the upstream concrete shield.

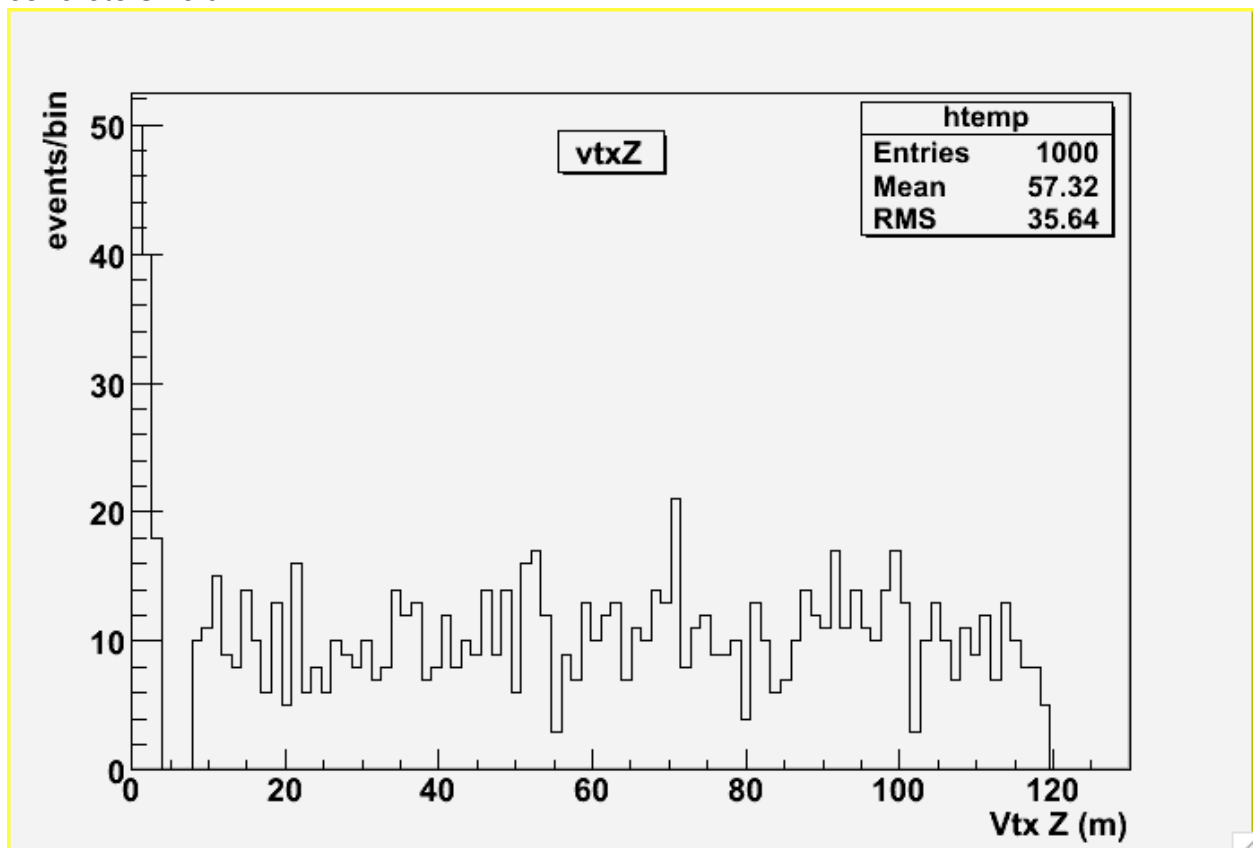


Fig. 2: The truth vertex Z distribution for the high statistics run without the shield.

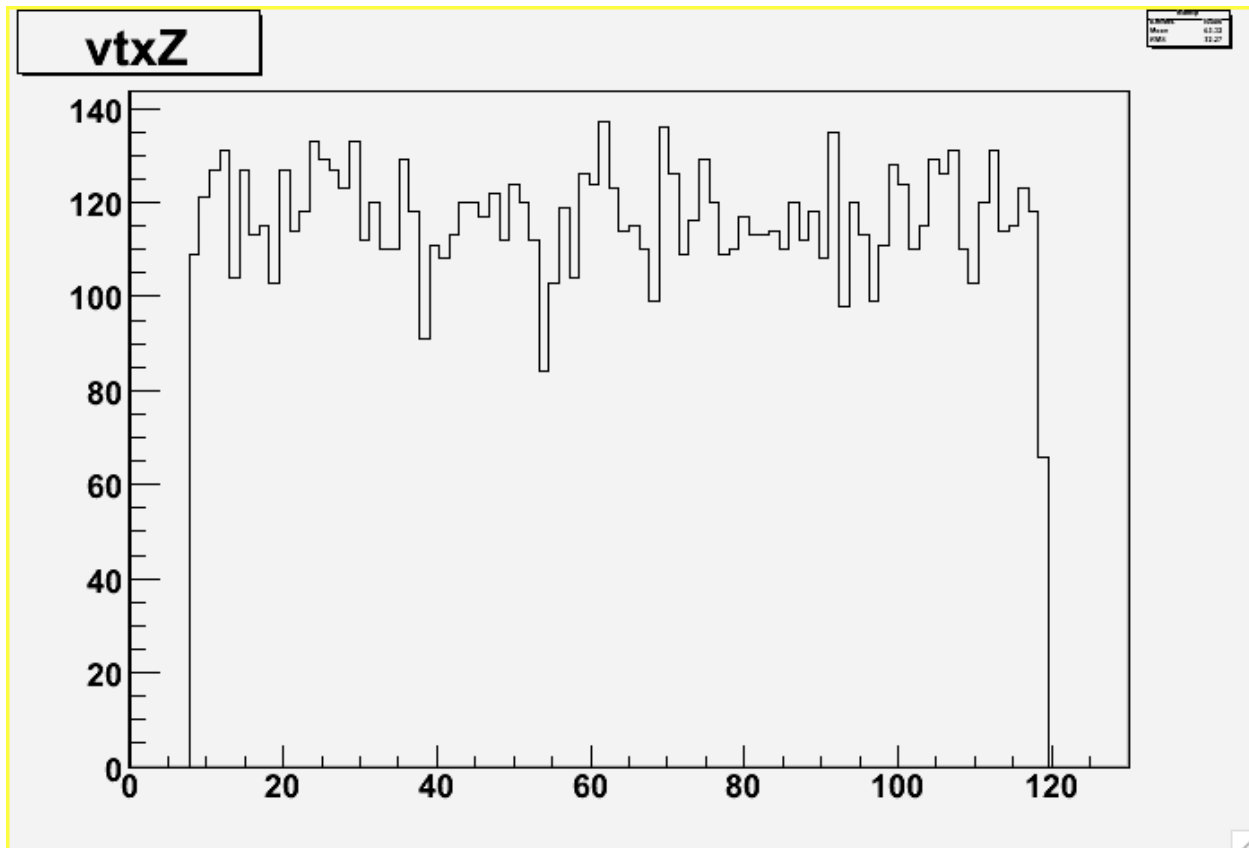


Table 1 lists the comparisons made between the observed distributions and the intended geometry of the CDR. The total detector length in the table was calculated from the highest and lowest observed vertex positions of 10000 events to be 110.006m, compared to the expectation of 111.014m. The 90% CL of this sampling corresponds to an uncertainty of 2.55cm. The transverse extent of the vertex positions are within the design to less than 1mm. The Y-X, X-Z, and Y-Z shape profiles are all correct.

Fig. 3: The Y-X distribution of vertices.

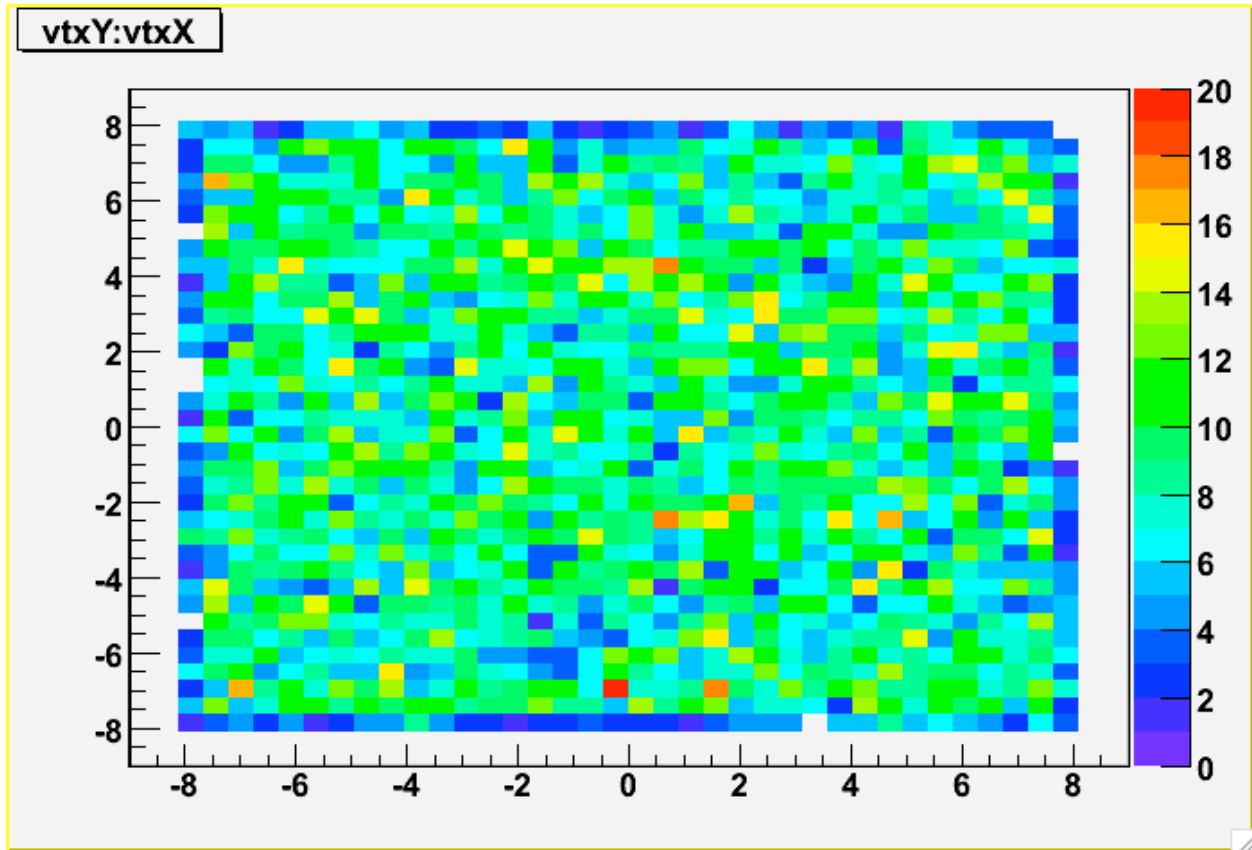


Table 1: Large scale geometry validation.

Quantity	Expectation	Observation
Position (Z)	1st vertex at 8m	8.002m
Position (X,Y)	Mean at 0cm in each	(0.12,0.07) cm
Size (Z)	6.6cm*31planes/block* 54 blocks+ 1cm*31 expansion gaps=111.014	111.006m
Size (X,Y)	15.7m each	(15.699,15.698) m

Fine Scale Geometry

The fine scale of the `cdrc_far` geometry was validated using approximately 22000 events, where the vertex was restricted to be in planes 10-12, and within 3m of the central Z-axis of the detector. Since vertex positions are chosen without regard to the sub-structure of an active plane (and only based on its mean density), the active Geant hits were used to illuminate the active cell structure.

Figure 4 shows the truth start and end hit position distribution, in T (transverse measured coordinate) vs. Z distribution, over the first 5m of the detector. The 1cm expansion gaps between blocks 1&2 and 2&3 are clearly visible.

Figure 5 is a finer version of figure 4, zoomed in around planes 12 and 13, within 5cm of the detector axis. The thicker webbing of the vertically oriented plane (13) is evident.

Table 2 summarizes the validation tests of the fine scale of the geometry. Sizes are calculated from histograms binned to 0.2mm in Z and 0.1mm in X and Y.

Fig. 4: Active cell truth hit start and end positions, T (X or Y) vs. Z. Vertices were generated in a 3m radius around the detector axis, in planes 10-12 only.

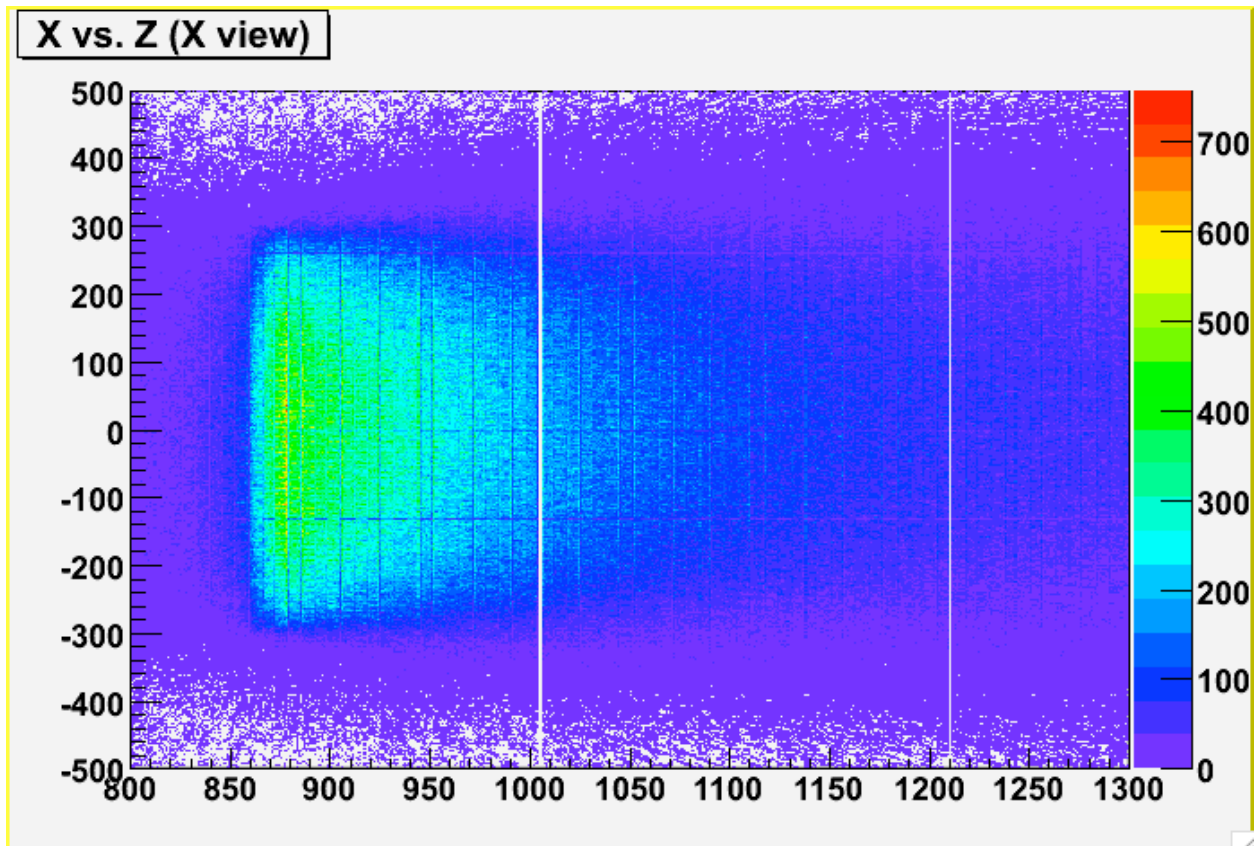


Fig. 5: Zoomed view of Fig. 4, zoomed in 5 cm around planes 12 (centered at 876 cm) and 13 (centered at ~883cm).

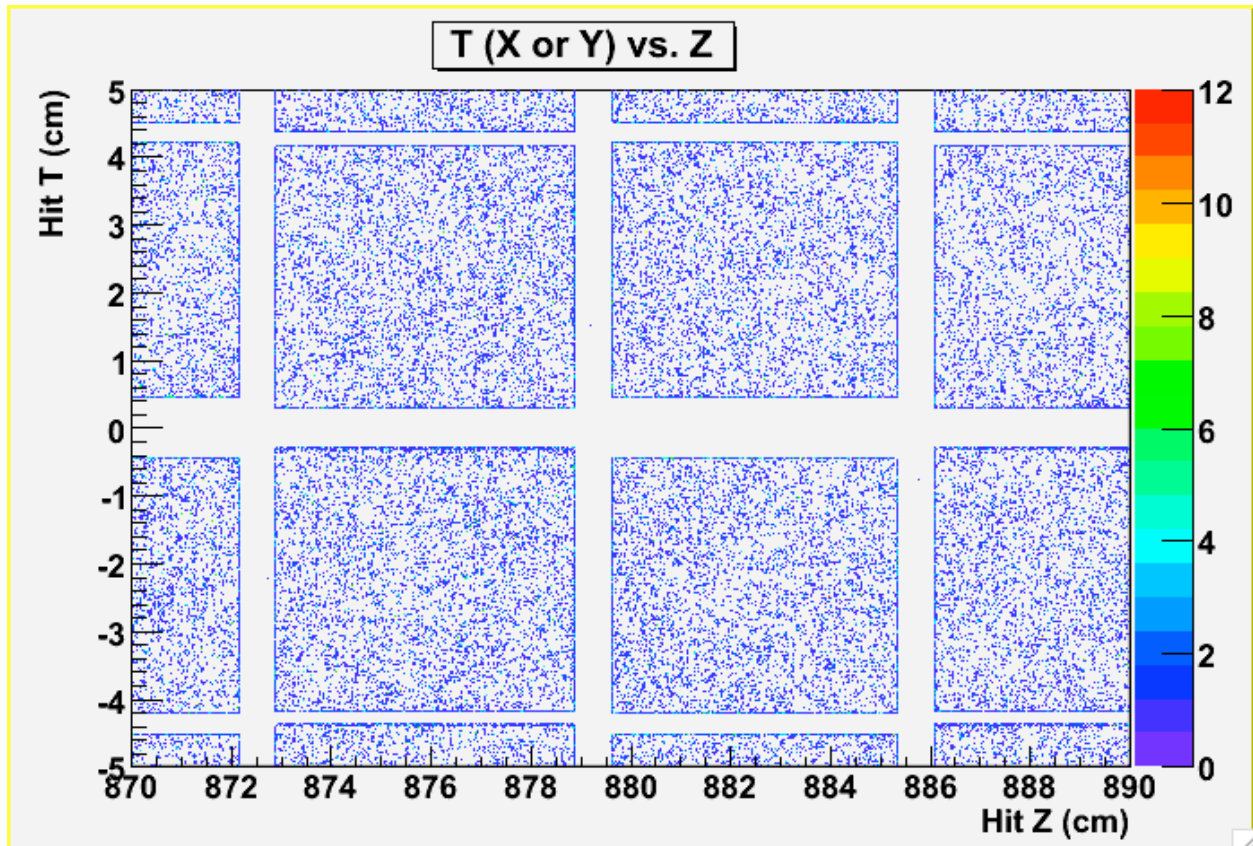


Table 2: Validation tests of the fine scale geometry.

Quantity	Expectation	Observation
Horizontal Cell Size	6cm deep x 3.87cm wide	6cm x 3.87cm
Vertical Cell Size	5.7cm deep x 3.76 cm wide	5.7cm x 3.76cm
Z Gap between horizontal cells	7.2cm = 6.6cm plane thickness+ 2 x 0.3cm horizontal outer wall thickness	7.205cm
Z Gap between vertical cells	7.5cm=6.6cm plane thickness + 2 x 0.45 cm vertical outer wall thickness	7.50cm
Y gap between horizontal cells (inner web)	0.2cm	0.2cm
X Gap between vertical cells (inner web)	0.3cm	0.3cm
Y Gap between adjacent horizontal extrusions	0.6cm (2 x 0.3cm horizontal extrusion outer wall thickness)	0.6cm
X Gap between adjacent vertical extrusions	0.9cm (2 x 0.45 vertical extrusion outer wall thickness)	0.91cm
Horizontal Extrusion centering	Mean of inside edge of inner cells in extrusions 6 and 7 on detector Y axis (0.0cm)	0.0cm
Vertical Extrusion centering	Mean of inside edge of inner cells in extrusions 6 and 7 on detector X axis (0.0cm)	0.0cm

All observations in table 2 agree to within the 0.02cm binning in Z and the 0.01cm binning in X and Y, with the exception of the gap between active cells in adjacent vertical extrusions. This appears to be due to a small rounding error in table 3.2 of the CDR. The effect is negligible in the representation of the detector geometry, since the gminos geometry builder spaces the cells equally within extrusions, and extrusions equally within planes, thus avoiding accumulation of significant errors.

Summary:

The `cdrc_far.ffr` file is validated to accurately and thoroughly represent the cell and plane geometry of the far detector as presented in the CDR. The cosmic shielding wall representation is preliminary, but serves to provide some level of activity from neutrino interactions upstream of the detector.